Did USAF Technology Fail in Vietnam?

Three Case Studies*

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IN EARLY APRIL 1997, the Air Force rolled out the F-22 stealth fighter. This highly sophisticated and very expensive aircraft carries the promise of continued American air dominance into the next century. The decision to use it for that purpose commits the Air Force, and the country, to a specific technology. Is this wise?

If history is any guide, the American record with military aviation technology is mixed at best. Contrary to the conventional wisdom, American airmen have not enjoyed overwhelming technological superiority in their conflicts. During World War I, US airmen flew European-designed, and, in most cases, European-built aircraft. In the early stages of World War II, Americans were shocked to learn that the Japanese Zero was better than the best US fighters in service. And toward the end of that conflict, the airmen again found themselves at a considerable disadvantage when they had to battle the more advanced jet-powered Me 262. Five years later in Korea, American airmen yet again engaged a superior flying machine, the Soviet MiG-15. What was the situation in the Vietnam War?

There are those who consider the Vietnam War as proof that technology has been overused or misused. Others view technology as the Sirens of Greek legend, luring America into the Southeast Asian war and onto the rocks of defeat. Critics write of blind technological fanaticism, hubris, and overconfidence as the United States attempted to fight a remote, antiseptic war. Leaving the rhetoric aside, how well did Air Force technology perform during the war?

Vietnam was not what the Air Force envisioned as its next conflict. Thinking in terms of a massive nuclear exchange, the airmen planned, equipped, and trained for nuclear war. In fairness, this was the direction from above, and it did give the United States a formidable offensive force and effective deterrent (Strategic Air Command) against Communist aggression. However, this emphasis

*This article is part of a longer study of Air Force technology from Vietnam through the Gulf War. A shorter version of the article was delivered at the annual meeting of the Society of Military History on 11 April 1997.

not only put the other services at a disadvantage, it also crippled other Air Force missions. Consequently, the Air Force story in Vietnam is how an air force designed for one kind of war performed in a drastically different one.

Clearly the US Air Force had problems in the Vietnam War, and some were with technology. This paper focuses on three examples of Air Force technology in the Vietnam War. These vary in type, demonstrate both success and failure, and thus are representative. They are the F-105, fixed-wing gunships, and precision-guided munitions (PGM).[1]

The F-105

The Republic F-105 Thunderchief in many ways symbolizes Air Force performance in Vietnam. It was an aircraft that looked good from any angle. It was fast and stable, a machine that pilots called "honest." It could carry a heavy bomb load a long distance at a high speed. In short, it was a fine aircraft, a pilot's plane, well designed for the single purpose of fighting a nuclear war.[2]

Just as the Korean War erupted in June 1950, the Air Force asked Republic Aviation to conceive a successor to its F-84F. What emerged was an aircraft designed around a bomb bay that could accommodate a nuclear weapon and extensive avionics to lighten the workload of the pilot flying at high speed and at low altitudes. This would allow Tactical Air Command to participate in nuclear warfare, which was the primary emphasis of the American military during this period. The F-105 could carry eight thousand pounds internally and another four thousand pounds externally and turned out to be the largest and heaviest single-seat American fighter up to that time. It replaced the F-100D as Tactical Air Command's principal aircraft. (It had twice the bomb load and 50 percent more speed than the F-100 Super Sabre.) It also mounted a rapid-firing 20 mm Gatling gun. To be very clear, however, the F-105 was primarily designed as a bomber, and its air-to-air fighter capability was secondary.

During its first flight on 22 October 1955, it exceeded the speed of sound. When the aircraft was modified into the B version, it featured such innovations as a "coke bottle" fuselage, "clover leaf" speed brakes on the aircraft's tail, and the all-flying tail.[3] The first squadron was equipped with the Thunderchief in 1959.[4]

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Republic's "Ultra Hog." Although designated as a fighter (the F-105), its size and weight, not to mention its bomb bay, brought this designation into dispute. Early on it was saddled with such uncomplimentary nicknames as "Lead Sled," "Ultra Hog," and "Thud."

mentary nicknames as "Lead Sled," "Ultra Hog," and "Thud." Some write that it earned a poor reputation mainly due to the poor reliability of the avionics and the pilot's unfamiliarity with the fighter. The aircraft's low in-commission rate and high cost of maintenance were both disturbing and frustrating. The aircraft and its systems were complex and new to the Air Force, and spare parts were short. More dramatic and more important to its reputation were crashes. An examination of the records of other fighters of the century series, however, indicates that at least early in its career (up to 53,000 flying hours), the Thunderchief's accident record was only bested by the F-106.[5] Regardless, it was the Air Force's primary strike aircraft during the decade of the 1960s and what the Air Force had when the Vietnam War began. It flew three-quarters of the Air Force's strike missions during Rolling Thunder, the American strategic bombing campaign against North Vietnam between 1965 and 1968.[6]

The F-105 did not fare well in combat. The Thunderchief served as a fighter-bomber but was limited by its avionics designed for nuclear, not conventional, missions. Ironically, the bomb bay was used to carry a fuel tank, not bombs. At low level it was the fastest aircraft of the war, but was at a disadvantage in air-to-air combat because of its lack of maneuverability.[7] More than half (397) of the 753 F-105Ds and Fs built were lost in the war. Overall, the F-105 had the highest loss rate of any US aircraft operating in Southeast Asia and over North Vietnam.[8] Why such heavy losses? The political restrictions certainly played a role, allowing the North Vietnamese to build up and adjust their defenses. Another factor was that the tactics that had been developed for a short nuclear war proved costly and inappropriate in a long conventional air campaign fought against extensive ground-based air defenses. The introduction of surface-to-air missiles (SAM) made matters even worse for the airmen. A third factor was the aircraft itself.

The F-105 was neither as rugged nor as survivable as its World War II predecessor, the P-47, which was rightly celebrated for its toughness. The Thunderchief was designed to fight a nuclear war in which the delivery of one nuclear weapon at low altitude and high speed was all that was required. Little thought was given to a campaign consisting of hundreds of missions extending over years. Therefore, survivability was not a major design consideration; ruggedness, redundant systems, armor, and the like were not priority items. In fact, some survivability factors were traded off to enhance other performance. Two such instances proved critical. First, the fighter's two sets of hydraulic lines were run close together, apparently to ease manufacture and maintenance, so that a hit on one could easily take out the other. A loss of hydraulic pressure caused the stabilizer to lock in the full "up" position, pushing the nose down. Second, the internal and bomb-bay fuel tanks were not self-sealing. Such was the combat norm since 1940, for good reason, as one 1950 study found that 80 percent of American, British, and German aircraft losses in World War II were directly caused by fire, most from damaged fuel systems. At the very least, even a small caliber hit could cause a leak. This helps explain why the F-105 was so vulnerable to fire and explosion, three times as likely as the McDonnell Douglas F-4 Phantom to be lost to fire or explosion.[9]

As early as December 1965, the F-105 was being unfavorably compared with the F-4, as it was believed that it was 1.5 to 2.5 times as vulnerable as the Phantom. One study indicated that when hit by hostile fire, the F-105 had a 15 percent higher rate of loss than the F-4. This led to a recommendation that the Thunderchief be shifted from action over North Vietnam to the less lethal skies of South Vietnam, and it spurred a number of studies to assess the vulnerability of the aircraft and search for remedies. One conclusion was that if the F-4 and F-105 were fairly compared (using similar time periods, similar missions, and similar risks), their loss rates were about the same.[10]

The Thunderchief was modified to deal with some of these problems. By mid-1965, the flight control system had been changed so that if the hydraulic system was hit, the pilot

"Puff." Top, dragon fire from the sky; right, Puff's teeth—a close-up of the three 7.62 mm miniguns;above, an AC-47 over South Vietnam. Fortunately, Air Force Chief of Staff Curtis LeMay ordered the C-47 gunship concept to be tested in Vietnam over TAC's objections.

could mechanically lock the horizontal stabilizer at an optimum setting. He could then use an electric toggle switch to control roll and pitch with the wing flaps along with differential engine power to fly the plane. This could at least get a pilot out of the immediate area before he was forced to eject from the stricken aircraft. A rocket ejection seat was fitted into the aircraft to enhance pilot survivability. Self-sealing tanks and bomb-bay fire extinguisher modifications were also added.[11]

It is hard to put a positive spin on the F-105's service in Vietnam. One might say diplomatically that its record could be called "mixed," but that really doesn't say anything. To cut to the heart of the issue, the F-105 could not overcome the limitations of its basic design, the peculiar conditions of the war, the role in which it found itself, or American tactics. At best, it proved to be a mediocre performer in difficult conditions. Similar to the military, it served honorably and capably in a losing cause. What more could be expected? The last F-105D unit returned to the US in late 1970, to be replaced by the F-4 in the fighter-bomber role.

Gunships

In contrast to the F-105, the fixed-wing gunship was a great developmental and operational success. A few dedicated, innovative individuals brought forth a new concept quickly and cheaply that fit the war that was being fought in Vietnam. The basic gunship concept is quite simple: an aircraft flying in a level turn around a point on the ground (as if tethered to a pylon, hence called a "pylon turn") can deliver fairly accurate firepower from guns firing perpendicular to the line of flight.[12] This concept was first proposed in 1926 and demonstrated the next year. A number of other airmen later advanced the idea, but the Army Air Forces/US Air Force did not pick up on it until the early 1960s.

The idea reached Capt John Simmons at Wright-Patterson AFB, Ohio, through an indirect route.[13] After overcoming numerous re-

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buffs, he pushed through a modest test program in mid-1963 that demonstrated that a pilot could track a target while in a pylon turn. The breakthrough came in August 1964 when a C-131 armed with a 7.62 mm Gatling gun achieved better than expected accuracy in firing tests over the Gulf of Mexico. The next month, three Gatling guns were mounted aboard a C-47 and also successfully tested. Capt Ronald Terry forcefully articulated a concept of C-47s delivering accurate and massive firepower to hamlets under attack. Things moved ahead rather rapidly, for on 2 November 1964 Terry helped brief the concept to the Air Force Chief of Staff Curtis LeMay, who ordered that the C-47 be tested in Vietnam.

There was opposition to the concept. Gen Walter Sweeney, commander of Tactical Air Command, had two seemingly contrary objections: could the aircraft survive, and if so, would it undermine the Air Force's position in the battle with the Army over armed helicopters? In addition, he did not see how the gunship would work in other conflicts, specifically one in Europe. Therefore, success in Vietnam might saddle the command with a number of aircraft that would prove useless and vulnerable where it really counted, in Europe. Certainly, the idea of using obsolete transports to support besieged hamlets at night, at low speeds, and from low altitudes did not appeal to the airmen, who thought primarily in terms of newer aircraft flying ever higher and faster. Nevertheless, the tests went forward.

Terry and his team arrived in South Vietnam in December 1964. The gunship quickly demonstrated that it not only worked but was valuable. On its first night mission on 23–24 December, it helped repel a Vietcong attack on an outpost.[14] The gunship concept would be used in two very different roles. The first was to provide heavy firepower to ground forces engaged in combat in South Vietnam. The other was to interdict enemy logistics in Laos. The aircraft's success continued, but better gunships were coming on-line. On 1 December 1969, US Air Force AC-47s flew their last mission.[15]

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In November 1966, the C-130 was picked as a follow-on aircraft. The four-engined turboprop had much greater flying performance than the ancient "Gooney Bird" and carried much heavier firepower, four 7.62 mm and four 20 mm Gatling guns compared to the AC-47's three 7.62 mm guns. Nicknamed "Spectre," it also mounted an array of advanced sensors.[16]

In September 1967, Captain Terry returned to Vietnam to test the AC-130. The evaluations concluded that the AC-130 was "a three-fold improvement over its predecessor, the AC-47."[17] The AC-130 was deemed the most cost-effective, close-support, and interdiction weapon in the USAF inventory.

Four AC-130s were sent into combat in Laos before the end of 1968 and proved to be some of the best weapons in the interdiction campaign. During the period January 1968 through April 1969, they flew less than 4 percent of the total sorties against moving targets, yet claimed over 29 percent of the destroyed and damaged trucks. Little wonder why the Air Force wanted more.

Concern about the gunship's vulnerability pushed the Air Force towards heavier armament to increase stand-off range. (Larger guns would also do more damage to targets.) In mid-1969, a group that included Major Terry suggested that two 40 mm[18] and two 20 mm guns become the standard armament. They also recommended better sensors (such as low-light-level television and improved infrared), a digital computer to replace the analog one, and a laser designator. A program dubbed "Surprise Package" that incorporated these ideas, got the go-ahead in September 1969. After a month of stateside test flights, the aircraft arrived in Thailand on 5 December for combat tests lasting through 18 January. The evaluators judged the improved model twice as effective as the existing C-130s.[19]

The last effort during the war to boost the AC-130's killing power was to mount a 105 mm howitzer.[20] While to the outsider this appears to be quite a feat, it actually was accomplished very smoothly. The gun saw combat during the 1971–72 dry season campaign and in Linebacker I, where it proved to be very effective, accounting for 55 percent of the tanks destroyed or damaged.

The third airframe used as a gunship was the C-119, another obsolete transport like the C-47, however not as esteemed. Nevertheless, it reinforced the gunship effort in late 1968 and became the most numerous of the Vietnam War gunships. The AC-119G was intended to take up the AC-47's mission in South Vietnam: defend hamlets, provide fire support for ground troops, and fly close air support and escort convoys.[21] While it served well, it was really little improvement over the AC-47.

The Air Force thought better of the AC-119K. The K model had increased engine power (two jet engines supplemented the two props), heavier armament (two 20 mm guns in addition to the G's four 7.62 mm guns), an improved fire control system, and forward

looking infrared radar (FLIR). Both AC-119 models did good work and suffered few losses. The AC-119Gs proved worthy successors of the AC-47 for operations in South Vietnam, while the AC-119Ks were able to complement the AC-130s in the interdiction campaign in Laos. In the overall scheme, the AC-119s were a midrange model between the "Model T" AC-47 and the "Cadillac" AC-130E.

The last challenge to the USAF in the Vietnam War came in 1972. By then the Communists had improved the Ho Chi Minh Trail into an extensive road net and greatly upgraded its defenses. The North Vietnamese upped the ante by deploying SAMs, both the large SA-2s and shoulder-fired SA-7s. Damage to the gun ships increased while truck kills declined. Even escorting fighters could not provide the gunships with the permissive air environment they required. The increased attrition, as well as the 1972 North Vietnamese invasion, forced the Air Force to shift its emphasis.

The main mission of American air power in 1972 was to thwart the North Vietnamese invasion. Certainly, the gun ships played an important role in that successful endeavor. The top American officer in the theater, Gen Creighton Abrams, told the Seventh Air Force commander, Gen John Vogt, that the three weapons that had been unqualified successes were the tube-launched, optically tracked, wire command (TOW) missile; the AC-130; and the guided bomb.[22]

Precision-Guided Munitions

PGMs were another success story. American airmen entered the Vietnam conflict armed primarily with free-fall bombs ("dumb bombs") that were no different from those used in World War I. Despite experiments with guided bombs in World War II and Korea, the Air Force had only two Navy air-to-ground missiles in 1965. The Bullpup, a rocket-powered, radio-control guided, 250-pound bomb, was used from the outset of Rolling Thunder. Its small warhead, however, was totally inadequate against North Vietnamese bridges.[23] The Navy's Walleye proved better. (It was an unpowered, 829-pound bomb guided by an automatic tracking television guidance, giving it a "launch and leave" capability.) The Air Force began Walleye combat tests in August 1967 that achieved excel-

An optically guided bomb. However, due to operating restrictions, cost, and the appearance of laser-guided bombs, these comprised only a small fraction (6 percent) of the total number of PGMs employed in Vietnam.

lent results in good visibility against targets that gave a strong contrast and were lightly defended.[24] Later Walleye operations in more demanding conditions were less successful. It continued to be used, but due to its operating restrictions, cost, and the appearance of laser-guided bombs (LGB), comprised only a small fraction (6 per cent) of the total number of PGMs employed in Vietnam.[25] The guided bomb of choice turned out to be based on a new technology: lasers.

The use of lasers in guidance applications was first discussed in 1958 and was later nourished by the Army as antitank seekers. But the Vietnam War skewed the Army in other directions as it recognized that Vietnam was not going to be a tank war. So the promising effort was passed on to the Air Force.[26] Laser-guided bombs were far enough along by mid-1967 to begin combat tests, during which the 750-pound bombs achieved an average error of 64 feet, and the two-thousand-pound bombs 32 feet. Over half were scored direct hits.[27] The tests continued. In 1969, 61 percent of 1,601 Mk 84 laser bombs released scored direct hits; the 85 per cent that were guided had an average error of 9.6 feet. As this was less than the bomb's lethal radius, bombing results were impressive.[28]

Nevertheless, the laser-guided bombs had their limitations. Smoke, haze, and clouds could nullify the weapon. One aircraft had to loiter in a predictable (and thus vulnerable) flight pattern (a circle) while the bomb fell to earth. There were some problems of reliability: in the initial tests, nine of the total 66 bombs suffered malfunctions. The seeker heads proved vulnerable to damage if flown through a rainstorm. Because of the system's undulating flight path, the bomb lost energy and had less stand-off range than did the Walleye.[29]

The Air Force pushed the laser-guided bombs. The laser kit could be fairly easily adapted to other bombs, and it was. By 1971, the Air Force was using five-hundred-, one-thousand-, two-thousand-, and three-thousand-pound bombs. But the smallest of these became the standard, not because of cost (it was only marginally cheaper), but because more of the lighter bombs could be carried on each sortie. Better accuracy permitted smaller payloads to be more effective.[30]

Meanwhile the Air Force was seeking to improve the weapon. Pave Knife was the code name for a system that consisted of a laser designating pod carried beneath the strike aircraft, making it both bomber and designator. Fewer aircraft could now do the same job, and were less vulnerable.[31]

This was the situation when the Communist Easter offensive of 1972 exploded. PGMs proved to be excellent weapons in two diverse roles in the 1972 campaign: precise bombing of the North Vietnam homeland and the repulse of the North Vietnamese army in the field.

Guided weapons were important in the attacks on North Vietnam for two major reasons. First, laser weapons allowed fewer aircraft to do greater damage, not only putting fewer men and machines at risk, but getting the job done the first time. In view of the effective North Vietnamese defenses, this was critical. Second, they achieved accuracies that permitted employment in close proximity to civilians, dikes, and the like. Two examples made this dramatically clear.

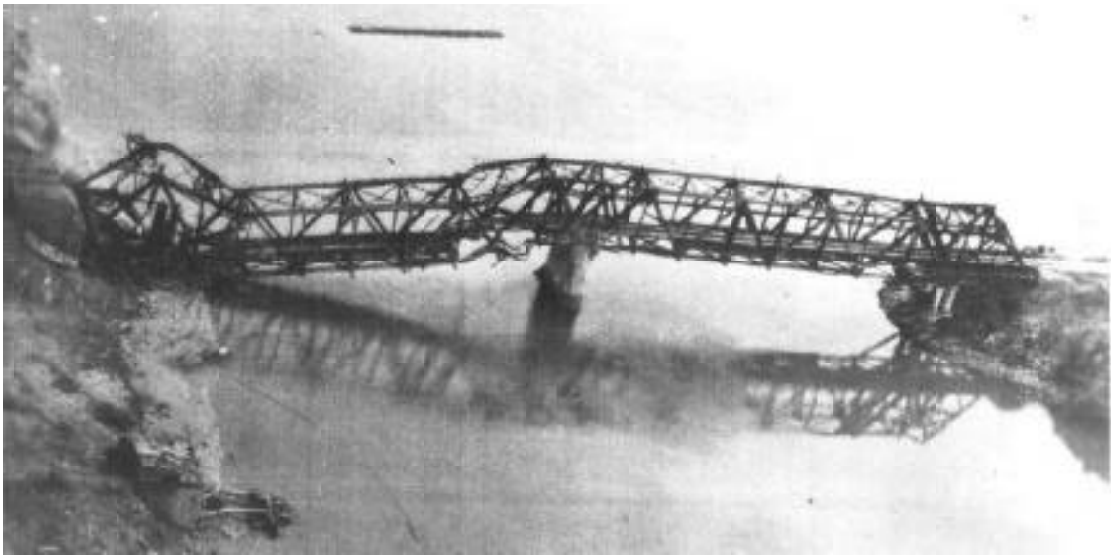
North Vietnamese bridges were prime targets in the effort to cut off supplies from the fighting in the South. Symbolic of this long, frustrating, and deadly duel between American airmen and North Vietnamese defenders throughout the war was the Thanh Hoa ("The Dragon's Jaw") Bridge.[32] Prior to Linebacker I, it had withstood 871 Air Force and Navy sorties and cost 11 aircraft.[33] On 13 May 1972, 14 bombers dropped both laser-guided and dumb bombs that scored several hits, knocking one of the main spans off its abutment and closing the bridge to rail traffic for the rest of the campaign.[34]

Another example of the confidence that the laser weapons gave the American airmen was the attack on the power-generating plant at Lang Chi Reservoir. Its proximity to a major dam put this key target off limits to the airmen with conventional bombs. In June 1972, the Air Force used LGBs to knock out the generating facility without causing any damage to the dam.[35]

The USAF pushed the laser-guided bombs. The laser kit could be fairly easily adapted to other bombs, and it was. By 1971, five-hundred-, one-thousand-, two-thousand-, and three-thousand-pound bombs were being used. Above: Two Mk 82 five-hundred-pound bombs with laser kits on an F-4C. Below: A three-thousand-pound LGB.

The guided bombs also proved valuable in fighting the conventional war in the South. Airpower was really the only weapon that could blunt two new and major Communist equipment advantages in the assault—tanks and 130 mm artillery. Airpower was about all that could get at these guns that outranged anything in the South Vietnamese army. Laser-guided bombs were also very effective tank killers: while the LGBs were involved in only 10 percent of the antitank effort, they were credited with 22 percent of the tank kills. Laser bombs also could take out bridges and thus seriously impede the advancing tanks.[36]

The advantage of the guided bombs is starkly revealed when compared with the F-105's work in the same areas (Route Packages VIA and VIB). The F-105s achieved a circular



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error probable (CEP) of 447 feet and 5.5 percent direct hits during the end of Rolling Thunder, compared with guided bombs' CEP of 23 feet and 48 percent direct hits during the period of February 1972 through February 1973.[37] One study found that LGBs were one to two hundred times as effective as conventional bombs against very hard targets and 20 to 40 times against soft and area targets.[38] General Vogt stated that laser weapons were about a hundred times as effective as dumb bombs.[39]

What is the explanation for the success of the guided bombs? As with gunships, a few innovative, motivated individuals pushed a promising idea forward. In a similar fashion, the key seems to be the simple and cheap technology. Because it was cheap, the program at first was low profile, allowing exceptional freedom of action. The low cost also permitted a competition to be held that not only demonstrated the overall concept of laser guidance, but also indicated that the technology that seemed the riskier of the two, was worth pursuing. Low cost also meant that testing could be repeated, allowing the device to be modified and fine-tuned before entering combat, in contrast to the F-111 (a story that is beyond the scope of this article). Its simplicity not only kept costs down, but made it a reliable and workable weapon. There was good cooperation between the manufacturer (Texas Instruments) and the customer (Eglin AFB, Florida). Design specifications were relatively loose, and military standards were not applied until late in the process. One student of the weapon concluded that flexibility was one of the key factors of success.[40]

Observations

What observations can be drawn from this brief look at US Air Force technology in the Vietnam War? First, the airmen can get off the hook, a little at least, for their inadequate

technology early in the conflict in that they designed their weapons for the war their civilian superiors demanded: nuclear war. While it is true that the military does not pick the wars it fights, it does pick the technologies it uses. The problem is the interface between the war and the technology. Second, airpower is more than flying. Contrary to what laypeople, most buffs, and some academics (and I fear perhaps some airmen) believe, airpower is more than airframes. Not only is it dependent on nontechnological factors (strategy, tactics, and training), but also on associated equipment such as munitions. The failure of the F-105 and the successes of the obsolete C-47s and C-119s as weapons platforms and the great increase in effectiveness from the use of laser-guided bombs underscore this point. A third observation is that Vietnam demonstrates the problems of an asymmetric war. This was *not* a total war for the United States; this was *not* the worst-case scenario of fighting an equivalent power with equivalent technology and probably greater numbers. Fourth, the military chooses to forget the lessons of Korea (for example, the difficulties of fighting a nonindustrial country, the problems of night interdiction, and the restrictions of a limited war), while the politicians were dominated by that war and the fear of Chinese intervention. The Air Force was not trying to fight the last war, as the military is so often accused of doing. It was trying to fight the next war. It was the civilians who were refighting Korea. Finally, simple is better. The highly sophisticated, complex, and expensive F-105 did not do well. In contrast, the simple, reliable, maintainable, and cheap AC-47 proved very effective. In a similar manner, the relatively low-cost laser-guided bombs permitted changes and testing that led to both tactical and manufacturing success.

In brief, then, the Air Force came into the Vietnam War woefully unprepared for the war it had to fight. While it is true that air operations were constrained by civilian-imposed restrictions, the Air Force had also limited its abilities by its concentration on nuclear war. It rose to the challenge of the war in Vietnam but paid a high price. The Air Force that conducted successful operations in the 1972 Linebacker I and II campaigns was different than the one that met defeat earlier in Rolling Thunder. But the war had also changed from a guerrilla war to a conventional one.

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Technology is important, but it is only one factor in fielding a capable and winning air force. What failed in Vietnam was not the technology, but a broad understanding of the power and limits of both airpower and air technology. One of the major characteristics of both is flexibility. It is this general lesson that should be carried forward into planning for Air Force operations in the next century. □

Notes

1. Other possible choices include aircraft such as the F-4 and F-111; sensor technology (Igloo White); modifications to the B-52 ("Big Belly" and Skyspot); drones (Buffalo Hunter); anti-SAM (Iron Hand, antiradiation missiles, radar homing and warning [RHAW]); and the list goes on.

2. Marcelle Knaack, *Encyclopedia of US Air Force Aircraft and Missile Systems*, vol. 1, *Post–World War II Fighters, 1945–1973* (Washington, D.C.: Office of Air Force History, 1978), 204; Jerry Hoblit, "AF-105 Thunderchief," 87, 89 in Robin Higham and Abigail Siddall, eds., *Flying Combat Aircraft of the USAAF-USAF* (Ames, Iowa: Iowa State University, 1975), 87, 89; and USAF Oral History Program, interview with Robinson Risner, 12 March 1983, Historical Research Agency (HRA), K239.0512-1370.

3. J. C. Scutts, *F-105 Thunderchief* (New York: Scribner's, 1981), 113; USAF Oral History Program, interview with Gen James Ferguson, 8–9 May 1973, 40–41, HRA K239.0512-672; Enzo Angelucci and Peter Bowers, *The American Fighter* (New York: Orion, 1987), 355, 407–8; Robert Archer, *The Republic F-105* (Fallbrock, Calif.: Aero, 1969), 9; Ray Wagner, *American Combat Planes* (Garden City, N.Y.: Doubleday, 1982), 472; and Theodore van Geffen Jr. and Gerald C. Arruda, "Thunderchief," *Air University Review* 34, no. 2 (January–February 1983): 48.

4. Angelucci and Bowers, 408; Knaack, 195–96; and Wagner, 472.

5. In 1964, 38 F-105s were lost to explosions or fires, 12 in the first four months. The most costly in terms of reputation was a fatal accident in May 1964 by the Air Force's highly prestigious and visible stunt team, the Thunderbirds. This was the F-105's sixth and last performance in the stunning Thunderbird colors. The team went back to flying F-100s for that season and never again flew the F-105s. There were at least six groundings of the aircraft. Van Geffen and Arruda, 54, 56; Scutts, 22–23; Knaack, 194–95; David Anderton, *Republic F-105 Thunderchief* (London: Osprey, 1983), 13; and Donald Sorlie, "An Analysis of the F-105 Weapons System in Out-Country Counter Air Operations," Air War College case study, (Maxwell AFB, Ala., Air University, April 1968), 27; and Archer, 57.

6. Delbert Corum, "The Tale of Two Bridges," in *Air War-Vietnam* (Indianapolis: Bobbs-Merrill, 1978), 12.

7. It had been built for speed at low altitude, and its large size, heavy weight, and relatively small wing did not permit fighter-like maneuverability. Of 332 F-105 combat losses, 22 were credited to MiGs in air-to-air combat. In exchange, the F-105s claimed 27.5 MiGs. Tactical Air Command, "Summary of USAF Aircraft Losses in SEA," June 1974, 25, HRA K417.0423-16; and R. Frank Futrell et al., *Aces and Aerial Victories: The United States Air Force in Southeast Asia, 1965–1973* (Maxwell AFB, Ala.: Albert F. Simpson Historical Research Center, 1976), 117–25, 157.

8. To be precise, over North Vietnam the F-100 and the USAF-manned A-l had higher loss rates, but together they flew less than 6 percent of the sorties flown by the F-105 over the North. Michael McCrea, *US Navy, Marine Corps, and Air Force Fixed-Wing Aircraft Losses and Damage in Southeast Asia (1962–1973)* (Arlington, Va.: Center for Naval Analysis, August 1976), 1-4 through 1-6; and "Summary of USAF Aircraft Losses in SEA," 22, 38.

9. John Guilmartin, "Editorial Note," *Air University Review* 34, no. 2 (January–February 1983): 53. Deleting the self-sealing feature saved six hundred pounds. A 1967 Wright-Patterson study stated that fires were reported in 50 percent of the F-105 losses. Patrick G. Long, "Evaluation of F-105 Weapon System in the Role of Out-Country Interdiction [in] Southeast Asia, 1965–1967," Research Report no. 3633 (Maxwell AFB, Ala.: Air War College, 1968), 61–62. Another study that year indicated that fires and explosions were suspected as the major cause of loss in 45 percent of 42 F-105 losses, and in 16 percent of 44 F-4 losses. Max Cleveland et al., "Vulnerabilities of the F-4C and the F-105 Aircraft to Ground Fire in SEA," August 1967, 10, 20, 22, HRA K740.01-25; and Warren Greene, "The Development of the B-52 Aircraft, 1945-53,"11 May 1956, 44–45, HRA K243.042-1.

10. Robert Hiller and Philip Conley, "A Comparison of the Vulnerabilities of the F-105 and F-4 Aircraft to Ground Fire," December 1965, HRA K717.3101-11; and Cleveland, 114.

11. The previous ejection seat required a one hundred-foot altitude and 120-knot minimum airspeed to operate successfully; the rocket seat could successfully operate at zero altitude and an 85-knot minimum airspeed. Scutts, 68, 85; and Sorlie, 27–28.

12. The essential source on this topic is the well-detailed and documented study by Jack Ballard, *The Development and Employment of Fixed-Wing Gunships, 1962–1972* (Washington, D.C.: Office of Air Force History, 1982). Unless otherwise noted, this section is drawn from Ballard. A briefer account that summarizes Ballard focuses on the AC-47 and adds a few tidbits is Lawrence Greenberg's undocumented "Spooky: Dragon in the Sky," *Vietnam*, 1 April 1980.

13. Gilmour MacDonald proposed variants of it three times during his AAF/USAF career, in 1942, 1945, and 1961. MacDonald passed the idea along to Ralph Flexman of Bell Aerosystems in late 1961, who carried the idea forward. Flexman, an Air Force reservist with a mobilization assignment at Wright-Patterson AFB, Ohio, suggested the concept to Simmons.

14. The tracers from the aircraft's three miniguns carved a fiery arc through the air, and along with the guns' distinctive roar, earned it the nickname "Puff" and "Dragonship" after the popular Peter, Paul, and Mary song of the day, "Puff the Magic Dragon." Later the AC-47 gunship would be given the radio call sign and the name for which it would be remembered: "Spooky."

15. The aircraft were turned over to the Laotian and South Vietnamese air forces. In their combat service in Vietnam, the AC-47s fired 97 million rounds and were credited with successfully defending almost four thousand hamlets, outposts, and forts and killing fifty-three hundred enemy troops. In all, 53 C-47s had been converted into the gunship version. Seventeen were listed as combat losses and two as operational losses. "Summary of USAF Losses in SEA," 22. In World War II, the AAF fired 197 million rounds in the European theater and 91 million rounds in the Mediterranean theater. "Army Air Forces Statistical Digest: World War II," prepared by the Office of Statistical Control, US Army Statistical Control Division, 1945, 245.

16. These included the Starlight Scope (called night observation device [NOD]), side and forward looking radar, and forward looking infrared radar (FLIR). Kenneth Werrell, "Did USAF Technology Fail in Vietnam?" (paper presented to the Society of Military History, Montgomery, Ala., 26 April 1997), 22.

17. Ballard, 89.

18. One improvement was to develop a more potent 40 mm projectile. A standard round was fitted with a misch-metal liner, a metal resembling cigarette-lighter flint. Combat tests in January 1971 indicated that it set off four to five times as many fires and explosions as did the standard round.

19. A later Seventh Air Force report on Commando Hunt III (1969–1970) credited the Surprise Package AC-130 with 7.34 trucks destroyed or damaged per sortie compared with 4.34 for the other C-130s, 3.12 for the AC-123, and 2.27 for the AC-119. A sensor that detected truck-engine ignition emissions (Black Crow) and a processor to integrate its signals along with infrared and low-light television were added to the AC-130.

20. The 105 mm projectile carried 5.6 pounds of high explosive compared with the 0.6 pounds carried by the 40 mm projectile.

21. In May 1968, the Air Force called personnel from an Indiana-based C-119 Reserve unit to active duty to crew the gunship. This was one of the few Reserve units to serve in the war.

22. Ballard, 243.

23. The best on this subject is David Mets, "The Quest for a Surgical Strike: The Air Force and Laser Guided Bombs" (Eglin AFB, Fla.: Air Force Systems Command, October 1987). Unless otherwise noted, all material in this section is from this source.

24. Through 8 November, the Air Force dropped 22 Walleyes and scored 13 direct hits and two near hits.

25. During the course of the war, the Air Force expended 206 Walleyes and 545 of its later version, the homing bomb (HOBO) system. Donald Blackwelder, "The Long Road to Desert Storm and Beyond: The Development of Precision-Guided Bombs" (thesis, School of Advanced Airpower Studies, June 1993), 18. About 69 percent of the 774 Walleyes dropped by the Navy scored direct hits. The electro-optical guided bomb (EOGB) was more costly than the LGB ($17,000 versus $4,700). Other disadvantages of the TV-guided sensor was that it was restricted to daytime use and required modification of the aircraft. "Linebacker: Overview of the First 120 Days," Contemporary Historical Evaluation of Counterinsurgency Operations (CHECO) report, Headquarters PACAF, September 1973, 21; Patrick Breitling, "Guided Bomb Operations in SEA: The Weather Dimension, 1 February–31 December 1972," CHECO report, 1 October 1973, 27; Blackwelder, 18; A. Starr et al., "Evaluation of Guided Bomb Systems Employed in Southeast Asia," Institute for Defense Analysis, May 1974, 7, 27; Mets; and Melvin Porter, "Second Generation Weaponry in SEA," September 1970, 3–4, 8–12, 15–6 HRA K717.0413-80.

26. It also specified an error of no more than 25 feet, a guidance reliability of at least 80 percent, and the capability of

delivery from either dive or level-aircraft attitudes. Texas Instruments (TI) had already begun tests at Eglin that revealed a number of significant problems that were corrected. One major change was to add a canard configuration. This put the complete guidance package in the nose, which made it simpler to build and handle, and enhanced reliability and made it adaptable to a large number of Air Force bombs. Another change was to spin (or rotate) the bomb at a specific rate to smooth out the undulations of TI's "bang-bang" controls. This also helped cancel out electronic and aerodynamic errors. Peter DeLeon, *The Laser-Guided Bomb,* RAND Report 1312-1 (Santa Monica, Calif.: RAND, June 1974), 1–27; and Mets. An F-4 flew a pylon turn to keep the target in the laser beam while the bomb was falling. A second aircraft dropped the bomb from a dive into a "cone" or "basket" that at 10,000 to 12,000 feet measured about a mile across. Once it released the bomb, the strike aircraft could depart, but the designator had to remain and "laze the target until the bomb impacted about thirty seconds after bomb release." "Second Generation Weaponry," 20; and Mets.

27. The difference in accuracy between the two bombs was attributed to the tail fins. Because of its inferior accuracy and lesser cratering capability (35 feet wide and seven feet deep versus 49 feet wide and 13 feet deep), the testers recommended that the M-117 be discontinued. "Second Generation Weaponry," 21–23; and Mets.

28. "Second Generation Weaponry," 30–35.

29. A 1968 study indicated aircraft dropping PGMs took two to three times the number of flak hits as those dropping dumb bombs. James G. Burton, *The Pentagon Wars: Reformers Challenge the Old Guard* (Annapolis: Naval Institute Press, 1993), 10; Charles T. Fox, "Precision-Guided Munitions: Past, Present, and Future," defense analytical study, Maxwell AFB, Ala., Air War College, 14 April 1995; "Second Generation Weaponry," 22–23; and Mets.

30. Other aircraft in addition to the F-4s became laser designators, including the AC-130 Pave Spectre gunships, Pave Nail OV-10 forward air controllers, and Tropic Moon III, B-57G long-range, interdiction aircraft. Porter, 44–45; Starr et al., 5; and Mets.

31. Mets.

32. Located 75 miles south of Hanoi, the 540-foot-long bridge had only been opened to traffic in 1964. It was listed as target number 14 (of 94) on the airmen's 1965 target list.

33. The Air Force also tried another type of munition to destroy the bridge. On the last two days of May 1966, it attempted to float a number of five-thousand-pound mass-focus bombs down the Song Ma River to take it out. The bridge survived; one C-130 and one P-4 did not. Corum, 52–55, 59; and Sam McGowan, "Bridge at Dragon's Jaw," *Vietnam,* Summer 1989, 34, 36.

34. Walter Lynch, "An Analysis of Guided Bomb Systems Employment Effectiveness against Bridges during Linebacker I," August 1975, ii–iv, 5, 17, 29; Mets; Melvin F. Porter, "Linebacker: Overview of the First 120 Days," 24; and Corum, 84–85.

35. Mets.

36. Blackwelder, 16–17; and Mets. EOGBs were primarily employed in low-threat areas. During 1972, 329 were launched, and 53.5 percent achieved hits. In comparison, 9,094 LGBs were dropped, and 47.5 percent achieved direct hits. I assume that the EOGB "hits" are the same as the "direct hits" of the LGBs. Breitling, 20, 23–25, 28.

37. "Circular error probable" is the radius within which half of the bombs will fall. It should be noted that when these bombs were guided, they either scored direct or very close to direct hits. They were either "a go" or "no go." During this period, 15.2 percent of the guided bombs did not guide. Blackwelder, 16.

38. R. L. Blachly, P. A. Conine, and B. H. Sharkey, *Laser and Electro-Optical Guided Bomb Performance in Southeast Asia (Linebacker I): A Briefing,* RAND Report 1326-PR (Santa Monica, Calif.: RAND, October 1973), 3.

39. Vogt interview, 12 November 1972, in "Linebacker: Overview of the First 120 Days," 59. Analysts calculated that during Linebacker II, LGBs were about 15 times as effective as visual-aimed conventional bombs. This may understate their capability as 32 of the 56 LGB sorties were aimed at radio communications facilities, the most difficult target set the airmen engaged during that operation. Also note that during the 11-day campaign, there were only eight hours of daylight with weather suitable for PGM operations. Herman Gilster and Robert Frady, "Linebacker II, USAF Bombing Survey," April 1973, 10, 22, 40–43, HRA K717.64-8.

40. DeLeon, 27, 32, 34–35, 40.

The best executive is the one who has sense enough to pick good men to do what he wants done, and self-restraint enough to keep from meddling with them while they do it.

—Theodore Roosevelt